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Metabolic syndrome and coronary heart disease in South Asians, African-Caribbeans and white Europeans: a UK population-based cross-sectional study

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Abstract *Aims/hypothesis:* The aim of this study was to study differences in the prevalence of the metabolic syndrome and its associations with prevalent CHD according to ethnicity and sex. *Methods:* We performed a combined analysis of two population-based cross-sectional studies conducted between 1988 and 1991 that followed identical protocols. Participants (aged 40–69 years) comprised 2,346 Europeans (76% male), 1,711 South Asians (83% male) and 803 African-Caribbeans (57% male) resident in west London. Fasting blood, overnight urine collection, clinical and anthropometric measurements were performed. Clinical history or major ECG changes defined prevalent CHD. The metabolic syndrome was defined according to the criteria recommended by the World Health Organization (WHO) and the National Cholesterol Education Programme (NCEP). *Results:* The prevalence of the metabolic syndrome was highest in South Asians (WHO, men 46%, women 31%; NCEP, men 29%, women 32%) and lowest in European women (WHO, 9%; NCEP, 14%). The prevalence of CHD was 10% in South Asian men, 9% in European men, 5–6% in African-Caribbeans and European women, and 2% in South Asian women. The metabolic syndrome was associated with prevalent CHD in European men [NCEP, odds ratio (OR)=1.6, 95% CI 1.2–2.4; WHO, OR=1.7, 95% CI 1.2–2.5] and South Asian men (NCEP, OR=2.1, 95% CI 1.5–3.1; WHO, OR=1.6, 95% CI 1.1–2.3). Associations with CHD were weaker in African-Caribbeans and were inconsistent among European women. *Conclusions/interpretation:* The current definitions of the metabolic syndrome give an inconsistent picture of cardiovascular disease risk when applied to different ethnic groups within the UK. Prospective studies are needed to validate workable ethnic-specific definitions.

Keywords Coronary heart disease · Epidemiological studies · Ethnic groups · Metabolic syndrome · Prevalence

Abbreviations ATPIII: Adult Treatment Panel III · CHD: Coronary heart disease · CVD: Cardiovascular disease · HOMA: Homeostasis model assessment · LBBB: Left bundle branch block · NCEP: National Cholesterol Education Programme · OR: Odds ratio · WHO: World Health Organization

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Introduction

In 2002, CHD and cerebrovascular disease together accounted for 30% of all deaths in England and Wales [1]. However, there are striking differences in the risks of CHD and cerebrovascular disease between ethnic groups. In England and Wales, compared with the general population, mortality from CHD is 50% higher in South Asians and is 50% lower in African-Caribbeans. Mortality from cerebrovascular disease is highest in African-Caribbeans and higher in South Asians when compared with Europeans [2].

During the late 1980s, the concept emerged of a syndrome of metabolic disturbances centred on insulin resistance and including impaired glucose homeostasis, central adiposity, dyslipidaemia and hypertension [3]. We have

previously reported higher prevalences of some individual components of the metabolic syndrome in UK South Asians and African-Caribbeans compared with Europeans [4]. However, two composite definitions of the metabolic syndrome have since been proposed by the National Cholesterol Education Programme (NCEP) Adult Treatment Panel III (ATPIII) report [5] and by the World Health Organization (WHO) [6] (Table 1). These composite measures have been shown to predict CHD risk, largely in European populations [7–13].

The aim of the present study was to investigate the prevalence of the metabolic syndrome and its association with CHD in South Asian and African-Caribbean populations in the UK.

Subjects and methods

Study design We studied the prevalence of the metabolic syndrome and its association with CHD according to ethnicity and sex using data collected during two cross-sectional population-based studies that were conducted to identical protocols between 1988 and 1991 (the Brent and Southall studies). Both studies have previously been described in detail [4, 14] and were approved by local research ethics committees.

Subjects Participants were aged between 40 and 69 years and comprised 2,346 white Europeans (76% male), 1,711 South Asians (83% male) and 803 African-Caribbeans (57% male). The term 'South Asian' describes people of Indian, Pakistani or Bangladeshi origin. Recruitment was mainly from random samples from GP practice lists stratified according to ethnicity and sex. Sixteen percent (n=795) of participants were recruited from four factories in west London, which were chosen based on the ethnic mix of their workforce. The Southall study, the source of all South Asians in this study, preferentially sampled men to address the original specific study objectives and aimed to recruit equal numbers of European and South Asian men; African-Caribbeans who appeared in the sampling frame were also included. A target random sample (ethnicity stratified) of 600 women supplemented the original sample. The Brent study aimed to recruit equal numbers of European and African-Caribbean men and women.

Assessments and biochemical measurements Ethnic group was assigned by the interviewer on the basis of name, appearance and country of birth, supplemented with direct enquiry in cases of doubt. Participants attended a local hospital or factory medical centre between 07:00 and 11:00 h following an overnight fast. Height, weight and blood pressure were measured, a resting ECG performed, and blood samples taken for measurement of plasma triglycerides, cholesterol, HDL cholesterol, glucose and insulin. ECGs were coded by two experienced coders who were blinded to all other information on each subject. Timed overnight urine collections were carried out and urine albumin measured. For participants not known to be diabetic, an oral glucose load was given and plasma glucose, insulin and triglycerides were measured 2 h later. Measurements for the two studies were made at the same hospital chemical pathology laboratory. A self-completion questionnaire included items on socioeconomic status, medical history and lifestyle.

Analyses Self-reported diabetes was taken to indicate known diabetes. Newly diagnosed type 2 diabetes, IGT or IFG were ascertained using both fasting and post-load values according the criteria defined by the WHO in 1999 [6].

Insulin resistance was assessed in the fasting state in terms of the fasting plasma insulin concentration [15] and the homeostasis model assessment (HOMA) index of insulin resistance, which is calculated using the following equation: fasting plasma glucose (mmol/l)×fasting plasma insulin (pmol/l)/22.5 [16]. OGTT glucose and insulin responses were used to estimate insulin resistance. The glucose and insulin concentrations at 2 h acted as indices of the overall OGTT responses, and these values were used in the formula proposed by Matsuda and DeFronzo [17]: square root of ([fasting glucose (mmol/l)×fasting insulin (pmol/l)]×[mean OGTT glucose (mmol/l)×mean OGTT insulin (pmol/l)]/3,330). Matsuda's formula can only be applied to participants who underwent OGTT (i.e. those who were not known to be diabetic in this study). Both the HOMA and Matsuda indices include glucose concentration in their calculation, which diminishes confounding due to

Table 1 Metabolic syndrome definitions

WHO definition [6]		NCEP ATPIII definition [5]
At least one of the following	Plus two or more of the following	At least three of the following
Fasting plasma glucose ≥6.1 mmol/l	Blood pressure ≥140 mmHg/90 mmHg	Fasting plasma glucose ≥6.1 mmol/l
Insulin resistance under euglycaemic–hyperinsulinaemic clamp conditions in the upper quartile for the background population under investigation	Triglycerides ≥1.7 mmol/l and/or HDL cholesterol <0.9 mmol/l (men), <1.0 mmol/l (women)	Blood pressure ≥130 mmHg/≥85 mmHg
IGT (2-h glucose ≥7.8 mmol/l)	WHR >0.90 (men), >0.85 (women) and/or BMI >30 kg/m^2	Triglycerides ≥1.7 mmol/l
Known or newly diagnosed diabetes	AER ≥20 μg/min	HDL cholesterol <1.04 mmol/l (men), <1.29 mmol/l (women)
		Waist circumference >102 cm (men), >88 cm (women)

deficient beta cell function at glucose levels below the conventional upper limits for normoglycaemia [18]. The HOMA estimates of insulin resistance are primarily influenced by hepatic insulin resistance [16], whereas the Matsuda index values, determined in the glucose-stimulated state, are primarily influenced by peripheral insulin resistance (mainly at the level of muscle). The use of these three estimates of insulin resistance (fasting hyperinsulinaemia, and HOMA and Matsuda indices) strengthens the ability of the study to detect significant insulin resistance. Unless otherwise stated, the results shown for the WHO metabolic syndrome include Matsuda's method of estimating insulin resistance [17] based on the entire non-diabetic study population.

Microalbuminuria was defined by a cutoff value for AER of >20 μg/min, as recommended by the WHO, rather than the albumin/creatinine ratio, which is prone to sex- and ethnic-specific variation due to its dependency on muscle mass and dietary protein intake [19].

Participants receiving treatment for hypertension were included in the hypertension categories for both definitions of metabolic syndrome, irrespective of their actual blood pressure measurements.

Age-standardised prevalences of the metabolic syndrome according to the two definitions were determined in the study population as a whole and in those without known or newly diagnosed diabetes in each of the groups classified according to ethnicity and sex.

CHD was defined as the presence of either a history of doctor-diagnosed angina or heart attack, or the presence of major Q-wave or left bundle branch block (LBBB) changes on ECG.

Logistic regression models were used to describe the associations between prevalent CHD and the metabolic syndrome. These associations are described in the study population as a whole and in those without known or newly diagnosed diabetes in each ethnic group, stratified according to sex and adjusted for age and smoking status (current, ex and never).

Age-adjusted averages were calculated for each component of the metabolic syndrome; natural log transformations were used to derive geometric means for variables with non-normal distributions. The average values for each component for participants with and without CHD, stratified according to ethnic group and sex, were compared. Statistical significance was accepted at less than 5%.

Results

Prevalence of the metabolic syndrome and components The age-standardised prevalence of the metabolic syndrome was highest in South Asians (WHO, men 46%, women 31%; NCEP, men 29%, women 32%) and lowest in European women (WHO, 9%; NCEP, 14%) (Fig. 1a, b, Table 2). With regard to sex, the prevalence of the metabolic syndrome as defined by the WHO was three times higher in African-Caribbean women than in European women, but only 1.5 times higher in African-Caribbean men. This sex–ethnicity interaction was significant ($p<0.001$). A similar interaction was obtained for the NCEP definition ($p=0.001$). The prevalence of metabolic syndrome was lower in all groups when participants with diabetes were excluded, although the same patterns remained in terms of ethnic group and sex (Table 2).

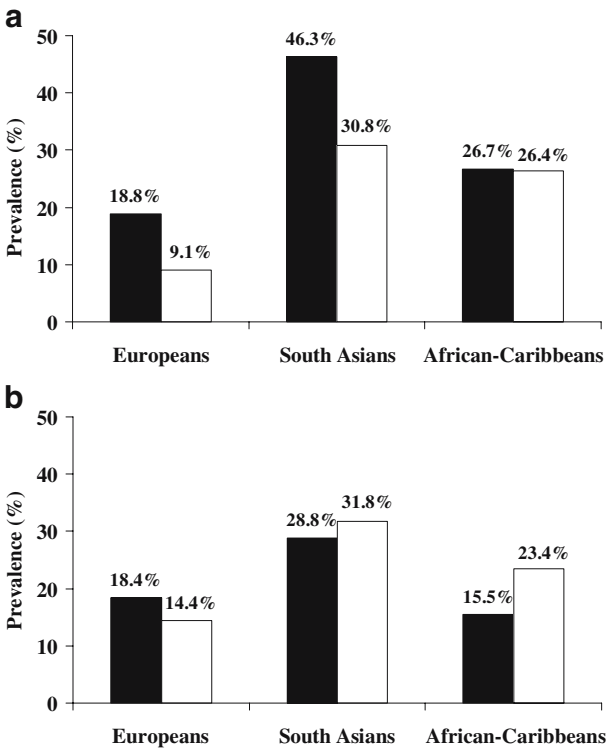

Fig. 1 Age-standardised prevalences of the metabolic syndrome as defined by the WHO criteria (**a**) or the NCEP criteria (**b**) in men (*black bars*) and women (*white bars*) divided according to ethnicity

While both definitions provided equivalent estimates for prevalence in European men, use of the NCEP definition provided a lower prevalence than the WHO definition in South Asian and African-Caribbean men. In contrast, the prevalence according to the NCEP definition was higher in European women and was similar for both definitions in South Asian and African-Caribbean women.

There was significant discordance between the two definitions of the metabolic syndrome. Of 1,540 participants identified by either definition, 767 (50%) were identified by both the NCEP and WHO definitions, 498 (32%) were identified by the WHO definition alone, and 275 (18%) were identified by the NCEP definition alone ($p<0.001$). The discordance between definitions was most marked in South Asian and African-Caribbean men.

Impaired glucose homeostasis was most prevalent in South Asians and African-Caribbeans (Table 2). The impaired glucose homeostasis category defined by the WHO identified 1,909 participants, whereas that defined by the NCEP identified only 1,070 participants; again, discordance was most marked in South Asians and African-Caribbeans. We compared the prevalences of the metabolic syndrome as defined by the WHO using either Matsuda's formula, the HOMA formula or fasting insulin concentra-

Table 2 Prevalences of the WHO and NCEP ATPIII definitions of the metabolic syndrome and its components

	WHO definition					NCEP definition				
	Europeans	South Asians	African-Caribbeans	*p* Value[a]		Europeans	South Asians	African-Caribbeans	*p* Value[a]	
				South Asians vs Europeans	African-Caribbeans vs Europeans				South Asians vs Europeans	African-Caribbeans vs Europeans
Men										
Total number	1,787	1,420	455			1,787	1,420	455		
Number with sufficient data to assign metabolic syndrome status[b]	1,717	1,322	424			1,776	1,397	443		
Metabolic syndrome (all participants)	18.8	46.3	26.7	<0.0001	0.001	18.4	28.8	15.5	<0.0001	0.11
Metabolic syndrome in people without diabetes	14.6	34.7	17.5	<0.0001	0.21	14.9	19.8	8.7	0.003	0.004
Known or newly diagnosed diabetes[c]	6.9	23.0	18.4	<0.0001	<0.0001					
Impaired glucose homeostasis[d]	27.3	57.5	45.7	<0.0001	<0.0001	16.9	30.0	31.2	<0.0001	<0.0001
Raised blood pressure and/or treated hypertension	24.2	36.3	38.1	<0.0001	<0.0001	39.1	53.4	55.6	<0.0001	<0.0001
Dyslipidaemia	38.7	52.8	22.3	<0.0001	<0.0001	44.5	60.1	28.4	<0.0001	<0.0001
Central obesity	73.9	92.5	73.1	<0.0001	0.95	16.2	17.6	11.2	0.30	0.002
Microalbuminuria (>20 μg/min)	*n*=1,055 (6.1)	*n*=763 (6.2)	*n*=290 (7.1)	0.94	0.49	–	–	–		
Women										
Total number	559	291	348			559	291	348		
Number with sufficient data to assign metabolic syndrome status[b]	548	281	327			551	286	338		
Metabolic syndrome (all participants)	9.1	30.8	26.4	<0.0001	<0.0001	14.4	31.8	23.4	<0.0001	0.0003
Metabolic syndrome in people without diabetes	6.8	20.0	17.1	<0.0001	<0.0001	12.2	22.6	16.3	0.003	0.15
Known or newly diagnosed diabetes[c]	4.2	16.6	18.9	<0.0001	<0.0001					
Impaired glucose homeostasis[d]	21.3	44.2	50.6	<0.0001	<0.0001	12.5	15.5	27.8	0.25	<0.0001
Raised blood pressure and/or treated hypertension	20.7	32.4	47.8	0.0002	<0.0001	30.2	47.6	60.2	<0.0001	<0.0001
Dyslipidaemia	25.9	37.8	13.8	0.0003	<0.0001	33.4	53.4	25.7	<0.0001	0.01
Central obesity	30.1	65.8	60.3	<0.0001	<0.0001	22.0	45.5	46.3	<0.0001	<0.0001
Microalbuminuria (>20 μg/min)	*n*=445 (2.7)	*n*=206 (3.0)	*n*=276 (7.5)	0.77	0.001	–	–	–		

The values shown are age-standardised prevalences (%)

[a]Mantel–Haenszel chi square test controlling for age

[b]Numbers given are those on whom prevalence figures for the metabolic syndrome are based

[c]Based on WHO 1999 criteria (fasting plasma glucose ≥7 mmol/l or OGTT plasma glucose ≥11.1 mmol/l or known diabetes) [6]

[d]For the WHO definition of the impaired glucose homeostasis component of the metabolic syndrome, insulin resistance was estimated according to the formula proposed by Matsuda and DeFronzo [17], and the upper quartile is based on the entire study population who were not known to have diabetes

tions to estimate insulin resistance. There was significant discordance between these three values with respect to the identification of insulin-resistant individuals, but this had little effect on either the absolute prevalence of the metabolic syndrome or its associations with CHD within ethnic groups stratified according to sex (results not shown). The prevalence of dyslipidaemia according to either definition was significantly higher in South Asians and significantly lower in African-Caribbeans compared with that in Europeans. Of those with the NCEP definition of the metabolic syndrome, 28% of Europeans and South Asians and 9% of African-Caribbeans had sufficient dyslipidaemia such that only one other component was required to identify them as metabolic syndrome 'cases'. The WHO central

Table 3 Prevalence of smoking and CHD, and odds ratios for associations between WHO and NCEP ATPIII definitions of the metabolic syndrome and prevalent CHD

	Europeans		South Asians[a]	African-Caribbeans	
	Men	Women	Men	Men	Women
Total number	1,787	599	1,420	455	348
Age-standardised prevalence, % (95% CI)					
Major Q-waves and/or LBBB on ECG	4.1 (3.2–4.9)	1.8 (0.6–2.8)	4.8 (3.9–6.2)	2.2 (0.8–3.6)	1.4 (0.2–2.7)
Previously diagnosed (by doctor) CHD	7.0 (5.8–8.1)	4.0 (2.4–5.5)	6.9 (5.6–8.3)	3.1 (1.5–4.8)	3.5 (0.2–5.5)
CHD defined by major ECG changes and/or previous diagnosis	9.1 (7.8–10.4)	5.6 (3.7–7.4)	9.8 (8.2–11.4)	5.0 (2.9–7.0)	4.9 (2.6–7.3)
Current smoking	31.8 (29.5–33.9)	30.0 (22.6–33.8)	14.9 (13.0–16.7)	26.5 (22.3–30.8)	8.9 (5.8–12.1)
Odds ratios for associations with prevalent CHD[b] (95% CI)					
WHO definition of the metabolic syndrome (all participants)					
Number[c]	1,713	546	1,315	422	326
Unadjusted	1.90 (1.33–2.72)	0.67 (0.15–2.90)	1.79 (1.22–2.61)	0.74 (0.27–2.04)	1.17 (0.39–3.45)
Adjusted for age	1.64 (1.14–2.37)	0.53 (0.12–2.31)	1.60 (1.09–2.36)	0.67 (0.24–1.86)	1.27 (0.41–3.90)
Adjusted for age and smoking status[d]	1.62 (1.12–2.34)	0.51 (0.12–2.24)	1.60 (1.09–2.35)	0.68 (0.24–1.89)	1.14 (0.36–3.65)
WHO definition of the metabolic syndrome (excluding those with known or newly diagnosed diabetes[e])					
Number[c]	1594	484	1031	284	262
Unadjusted	1.46 (0.94–2.26)	All CHD cases were without the metabolic syndrome	1.60 (0.99–2.6)	All CHD cases were without the metabolic syndrome	1.40 (0.37–5.29)
Adjusted for age	1.31 (0.84–2.05)		1.48 (0.91–2.40)		1.47 (0.38–5.69)
Adjusted for age and smoking status[d]	1.30 (0.83–2.04)		1.50 (0.92–2.44)		1.65 (0.41–6.64)
NCEP definition of the metabolic syndrome					
Number[c]	1,722	549	1,390	440	337
Unadjusted	1.88 (1.31–2.68)	3.96 (1.85–8.47)	2.31 (1.60–3.35)	1.12 (0.37–3.40)	1.87 (0.66–5.30)
Adjusted for age	1.65 (1.15–2.38)	3.26 (1.50–7.09)	2.04 (1.40–2.97)	1.05 (0.34–3.21)	2.02 (0.69–5.92)
Adjusted for age and smoking status[d]	1.60 (1.11–2.32)	3.38 (1.55–7.34)	2.11 (1.45–3.08)	1.08 (0.36–3.31)	2.03 (0.65–6.31)
NCEP definition of the metabolic syndrome (excluding those with known or newly diagnosed diabetes[e])					
Number[c]	1,639	522	1,085	324	268
Unadjusted	1.61 (1.05–2.45)	4.11 (1.82–9.28)	2.18 (1.33–3.57)	All CHD cases were without the metabolic syndrome	3.57 (1.11–11.5)
Adjusted for age	1.49 (0.97–2.29)	3.53 (1.54–8.07)	2.01 (1.21–3.34)		3.76 (1.15–12.33)
Adjusted for age and smoking status[d]	1.43 (0.93–2.21)	3.41 (1.48–7.86)	2.07 (1.24–3.44)		3.81 (1.09–13.21)

[a]South Asian women were excluded due to the small number (n=4) of CHD cases.
[b]CHD defined by doctor-diagnosed angina or heart attack, and/or the presence of major Q-waves or LBBB on ECG
[c]Number available for analysis
[d]Smoking status: current, ex, never
[e]According to WHO 1999 criteria (fasting plasma glucose >7 mmol/l or OGTT plasma glucose >11.1 mmol/l or known diabetes) [6]

obesity criteria applied to 93% of South Asian men, whereas the more discriminatory waist circumference criteria provided by the NCEP applied to only 18% (Table 2).

Approximately 37% of participants were missing AER data. The majority of those with missing AERs had sufficient other data to assign metabolic syndrome status; 199 (4%) participants could not be assigned WHO metabolic syndrome status due to missing AER data. Estimates of the prevalence of the metabolic syndrome (WHO definition) increased by only 0.06% when microalbuminuria was included in the definition.

Prevalence of CHD The prevalence of CHD as defined by the presence of major ECG changes or a previous diagnosis was similar in European and South Asian men (9 and 10%, respectively). European women and African-Caribbean men and women had lower prevalences of CHD (5–6%). Only four (1.4%) South Asian women had CHD, and these were excluded from analyses of associations between metabolic syndrome and CHD. Approximately two-thirds of cases with prevalent CHD in all subgroups had been previously diagnosed by a doctor (Table 3).

Associations between the metabolic syndrome and CHD South Asian and European men with the NCEP definition of the metabolic syndrome were approximately twice as likely to have prevalent CHD as those without (Table 3). This association persisted after adjustment for age and smoking. Use of the WHO definition produced a similar association in European men, but a weaker association in South Asian men. In African-Caribbeans, no significant associations were apparent between the metabolic syndrome (either definition) and CHD, although the odds ratio (OR) for the NCEP definition was 2.03 (95% CI 0.65–6.31) in women and the WHO definition appeared to confer some protection against CHD in men (OR=0.68, 95% CI 0.24–1.89). In European women, there was a strong association between the NCEP definition of the metabolic syndrome and CHD (OR=3.4, 95% CI 1.6–7.3), whereas this association was not present for the WHO definition of the metabolic syndrome (OR=0.51, 95% CI 0.1–2.2).

The exclusion of participants with known or newly diagnosed diabetes (according to the criteria adopted by the WHO in 1999) reduced the associations between the two definitions of the metabolic syndrome and CHD in European and South Asian men. Conversely, these associations were increased in African-Caribbean women, with the most marked increase observed for the NCEP definition of the metabolic syndrome, where the adjusted OR was 3.8 (p=0.04). In non-diabetic African-Caribbean men, all cases of CHD occurred in those without the metabolic syndrome (both definitions). In European women, the association between the NCEP definition of the metabolic syndrome and CHD was slightly higher in non-diabetic participants; however, there were no CHD cases in non-diabetic European women without the metabolic syndrome according to the WHO criteria (Table 3).

Comparison of the age-adjusted average values for the components of the metabolic syndrome for participants with and without prevalent CHD showed the expected trends of less favourable values in those with CHD. However, the differences between those with and without CHD were generally greater and more likely to be of statistical significance in Europeans than in other ethnic groups (see Table 1 of the Electronic Supplementary Material).

Discussion

This new analysis of the datasets from the Brent and Southall studies has identified marked differences in the prevalence of the metabolic syndrome between subgroups classified according to ethnicity and sex. South Asians had the highest overall prevalence of the metabolic syndrome, whereas Europeans had the lowest. Compared with the WHO definition, the NCEP definition provided lower prevalences of the metabolic syndrome in South Asian and African-Caribbean men, while the two definitions provided similar prevalences in South Asian and African-Caribbean women. Ethnic- and sex-specific variations in prevalence have also been observed in North American studies, but in different populations to those investigated in our study [20, 21].

Associations between the metabolic syndrome and prevalent CHD were strongest in European and South Asian men and, for the NCEP definition only, in European women; associations were weak or absent in African-Caribbean men —a pattern that was maintained when people with diabetes were excluded from the analyses. The exclusion of people with diabetes strengthened the association between the metabolic syndrome and CHD in African-Caribbean women. The observed associations between the metabolic syndrome and CHD in European men in this study are supported by findings from cross-sectional and prospective studies in European populations [7–22]. In our study, the metabolic syndrome as defined by the NCEP was more strongly associated with prevalent CHD than the WHO definition of the syndrome in all of the subgroups examined, apart from in European men. The San Antonio Heart Study found that the NCEP definition of the metabolic syndrome was more predictive of cardiovascular mortality than the WHO definition in lower-risk Mexican Americans and non-Hispanic white populations. Our findings of inconsistent or weak associations between prevalent CHD and the metabolic syndrome in European women and in African-Caribbeans may be related to the small numbers included in this study, but it is likely that absence of ethnic-group-specific validation of the metabolic syndrome definitions also contributes to the lack of association in African-Caribbeans. In general, compared with Europeans, UK African-Caribbean men tend to be insulin resistant and at high risk of diabetes, but have a favourable lipid profile and a low risk of CHD [23]. Due to this relative dissociation of insulin resistance and dyslipidaemia in African-Caribbeans, definition of the metabolic syndrome is problematic in this group.

The central adiposity and impaired glucose homeostasis components contribute to the excess prevalence of the metabolic syndrome as defined by the WHO in South Asian and African-Caribbean men compared with that defined by the NCEP. The impaired glucose homeostasis component of the WHO definition of the metabolic syndrome includes insulin resistance, IFG, IGT and diabetes. However, the impaired glucose homeostasis component of the NCEP definition, intended for routine clinical use, requires only IFG and thus may omit people with glucose intolerance or diabetes whose fasting glucose is within normal limits. In contrast, the NCEP definition is weighted towards the inclusion of men and women with lesser degrees of dyslipidaemia or elevated blood pressure and of women with lower levels of obesity. Both of these tendencies may apply differentially to the different ethnic groups.

Within the WHO definition there is scope for variation in the estimation of insulin resistance. The formula used in this study is conceptually attractive in that it combines estimates of hepatic and peripheral insulin resistance and closely approximated the euglycaemic clamp in a study group of diabetic and non-diabetic patients. As noted by the European Group for the Study of Insulin Resistance (EGIR) [24], with regard to the upper quartile of insulin resistance, 'it was not clear what the WHO consultation intended by the term "background population"...'. In this study we have used the entire non-diabetic study population as the background population as we believe this to be implied in the WHO definition. An alternative interpretation would involve the use of ethnic- and sex-specific upper quartiles, however, this automatically assigns 25% of all groups to the impaired glucose homeostasis category, and it is not clear that this approach is preferable given the known differences between ethnic groups in terms of cardiovascular risk.

The inclusion of microalbuminuria in the WHO definition has been challenged as unnecessary [15], while relevant data is seldom available in epidemiological studies. Extending the findings of the Data from an Epidemiological Study on the Insulin Resistance Syndrome (DESIR) study of European cohorts [24], we found that the presence of microalbuminuria had a minimal impact on the prevalence of the metabolic syndrome in any of the subgroups classified according to ethnicity and sex.

Both definitions of metabolic syndrome include widely accepted clusterings of risk factors for cardiovascular disease (CVD), and both are intended for clinical use as indicators of the risk of CVD. However, the variations in cutoff values, interpretations and the combination of components necessary to assign metabolic syndrome status result in substantial discordance between definitions. Importantly, neither definition recognises that the nature and contribution of each component may vary across ethnic groups. The metabolic syndrome definitions have been validated in European populations with reference to prediction of incident diabetes and CHD [7–13, 23], and modifications to the definitions have been suggested for use in European populations [24]. However, scant attention has been paid to the validation of the components and their cutoff values in other ethnic groups.

As in the US National Health and Nutrition Study [20], we found greater discordance between the WHO and NCEP definitions in non-Europeans.

In summary, this study demonstrates that, in a UK population, there are marked ethnic- and sex-specific variations in the prevalence of clusters of risk factors for CVD as described by recent definitions of the metabolic syndrome. In view of the observed variations in the association of the metabolic syndrome with prevalent CHD, a 'one size fits all' approach to defining the metabolic syndrome in different ethnic groups appears to be inappropriate. UK African-Caribbeans may be particularly poorly served by the current definitions of the metabolic syndrome given their differing risk factor profiles, and relatively low CHD mortality and high cerebrovascular mortality. In order for the metabolic syndrome to be an effective and practical indicator of cardiovascular risk, and hence a trigger for therapeutic intervention, prospective studies are needed to refine the definition by validating readily measurable components and their cutoff values against CVD morbidity and mortality in different ethnic groups.

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